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GROUND-WATER PROSPECTING IN TURKEY

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GROUNDWATER PROSPECTING IN TURKEY

by

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A - INTRODUCTION

Geographically Turkey is situated amid arid and semi-arid regions. The country spreads over two adjacent continents with Thrace, its smaller part in Europe and Anatolia, its larger part, in Asia. Generally speaking, Turkey is a peninsula surrounded by the Black Sea in the north, the Aegean Sea in the west, and the Mediterranean in the south. The Taurus ranges in the south and the Northern Anatolian ranges in the North, cross the country from East to West, parallel to the northern and southern coastlines. Parallel to the outer skirts of these ranges lie the Eastern and Southern Coastal Plains and the South-Eastern Anatolian Plains. The high plateau of Anatolia lies between these two ranges.

In the West, wide valleys and plains spread between mountain ranges that extend perpendicular to the shore lines. The Eastern regions of Anatolia are generally mountainous, with local high plains and plateaux.

The total surface area of Turkey is 776,980 sq.kms. and its present population is approximately 30 millions, of which 21 millions dwell in villages and 9 millions in towns and cities. Generally, population is denser in coastal areas where rainfall and surface water possibilities are favorable. Among many factors, rainfall and water resources play the most important part in the distribution of population over the country.

Areas where varying climates prevail exist in Turkey, depending on local topographical and geographical conditions.

Nevertheless, the major part of the country, outside of those areas where microclimatic conditions prevail, is essentially under the influence of arid and semi-arid climatic conditions. For example, in inland areas such as Central, Eastern and South-Eastern Anatolia, and the Western part of Thrace arid or semi-arid conditions prevail. In most of these regions rainfall is between 300-400 mm. or less; in others between 400-600 mm. at most. Further, rainfall occurs in winter and spring, well outside the growing season, while the weather becomes dry and hot during the growing season.

More than 70% of the population is engaged in agriculture. Since Turkey is now in the stage of slow industrial development, agriculture constitutes the mainstay of the national economy. Population growth is much higher in comparison with other countries.

In order to support these increments on the one hand and raise the standard of living of the whole population on the other, two things must be done :

1) Develop agricultural sources of supply to a level that will amply and economically meet the national demand,
2) Develop local industry to a level that will assist a rational agricultural development

Therefore, development of land and water resources and the application of modern irrigation methods in agriculture are matters of vital importance to Turkey.

As pointed out above, rainfall is generally low in Turkey. Therefore, it is imperative that irrigation water be supplied from other sources than just surface water alone in most agricultural areas. Turkey is divided into 26 different drainage areas The study of these has shown the surface sources of water-supply alone are far from meeting irrigation water demands, and resort must be made to groundwater sources to compensate for the deficit in surface water, by a simultaneous development of both. Some regions of Turkey are completely deprived of surface water. In these regions, groundwater is the only source of supply and must be developed rapidly. Besides its importance in irrigation water supply the subject of groundwater development bears an equally important value on village, town and city drinking water supply. There are actually 30,000 villages and towns

with no, or very little water, whatsoever. A reconnaissance survey has shown that, out of all such communities, in at least 8,000-10,000, household water must be supplied from underground sources.

On the basis of the above-mentioned facts, the development of our groundwater ressources to meet irrigation, drinking and household water demands, is a matter of prime importance.

B - AGENCIES ENGAGED IN GROUND-WATER PROSPECTING

The Ground-water Division of DSI is the largest organisation in Turkey that is engaged in ground-water, foundation and drainage investigation drilling.

Besides this state organisation there are a few smaller official, and private agencies also engaged in similar work, only on a much smaller scale.

(a) Government Agencies At present, the Electrical Investigation Administration (ZIKI), the Municipal Bank of Turkey (İller Bankası), the Mine Investigation and Prospection Institute (M.T.A.E.), the Directorate General of State Reproduction Farms, the Directorate General of Ankara and Istanbul City Water, the Sugar Plants Co., the Wool, and Mohair Cooperative, are the official or semi-official organisations engaged in drilling work in Turkey.

The (D.I.S.I) is engaged novadays only in foundation investigation drilling for large state construction work with half a dozen drill-rigs it owns and operates, although it has drilled water wells for a number of villages and towns in the past.

The Municipal Bank of Turkey has drilled in collaboration with a certain private company, drinking water wells for a number of villages and towns under 3000 population. Actually the Bank is planning to organise a drilling branch of its own to continue with drilling, along the same lines.

The (M.T.A.E) has also drilled a number of drinking and irrigation water wells in the past, indifferent parts of the country. The Institute is actually engaged in lignite and other mineral prospections only.

The Directorates General of Istanbul and Ankara municipalities, both and operate several drill-rigs for water supply purposes to meet these two cities water demands. The rigs are of the type that can drill shallow wells only.

The Directorate General of Sugar Plants is engaged in drilling wells for Farmers Unions and Sugar Cooperative in areas where sugar beet is produced in various regions of the country. The organisation owns and operates two 1500 capacity rotary rigs to do this job.

The Wool and Mohair Co. owns 2500' capacity rotary rigs with which it drills water wells in collaboration with a private firm.

Apart from these, the Directorate General of Land and Water, a state organisation attached to the Ministry of Agriculture, is actually organising and equipping itself with adequate machinery and personnel to drill production wells to supply irrigation water where it is needed.

(b) Private Agencies Besides the above mentioned official and semi-official agencies, there are approximately a dozen other private companies that own and operate a variety of drill rigs, of various types and capacities. Two of these companies own about ten 1500'or higher capacity rotary or percussion drill rigs operating in foundation investigation and deep well drilling. The remaining companies generally are just small organisations equipped with none but locally manufactured small rigs capable of drilling shallow wells only.

In addition to these agencies and companies, there are also a number of individual drillers, each owning one small rig, who are engaged in shallow well drilling to meet small individual demands. Although the exact number of these individual drillers is not known, it would not be too far off if we set it at 50, in all.

C - GROUNDWATER DIVISION OF THE DIRECTORATE GENERAL OF STATE HYDRAULIC WORKS

a) Functions Provisions in laws such as the "Groundwater Law and the Drinking water law for Villages and Towns" hold DSİ responsible for supplying water to meet the demands. Such responsibilities of DSİ relating to groundwater, are delegated to and accomplished by the Groundwater Division.

The main functions of the Groundwater Division consist of applying the groundwater prospection programmes by running hydrogeological and geophysical surveys, and drilling exploratory wells in every and all areas within the Turkish territory; recognizing as groundwater production areas, those areas where the investigations are completed and irrigation operations have proven satisfactory . and putting them into public use, together with the results of the investigations; drilling drinking and domestic water wells for communities with populations less than 3,000, and for military garrisons; drilling drainage and foundation investigation test holes relating to DSİ construction programme; studying groundwater possibilities and encouraging economical use of groundwater by substantial educational programmes and publications, and generally taking necessary protective measures in areas where groundwater is being pumped.

The Division accomplishes these functions either by force account or by partial contracts, as it sees fit .

b) Organisation The Groundwater Division is one of the nine similar Divisions of DSİ. All investigation, design, planning, general supervision, training and supply activities relating to groundwater, are transmitted to and handled by this Division. The Goundwater Law is enforced by DSİ Regional Directorates. Generally, groundwater foundation and drainage drilling operations are performed by force account by drill-camp organizations attached to DSİ Regional Directorates, under the close technical supervision of the Groundwater Division.

c) Personnel and Equipment at present, 18 drill-camps are operating, of which 5 are engaged in foundation, the remaining 13 are engaged in water and drainage investigation drilling. The Division employs a total of 167 personnel in Ankara, of which 68 are technical and 99 are aids. The camp organisations employ a total of 1,217 personnel, of which 54 are technical and 1,163 are aids.

New Groundwater Branch offices are being organised in every region of DSİ to take care of and supervise all groundwater activities within the region. In fact, within a year or two there will be one such branch office operating in every one of the 13 regions of DSİ.

DSİ owns quite an extensive park of drilling equipment . Included in the park are 44 drill-rigs engaged in groundwater exploration and drainage investigation drilling of which 31 are of the rotary, 13 of the percussion type; 25 drillrigs engaged in foundation investigation drilling, of which 11 are truck-mounted and 14 skidmounted; 3 resistivity, one seismic and 4 electrical well logging apparatus are engaged in geophysical investigations. In addition to all these, a variety of pump and motor units, compressors, generators, transportation and drilling equipments are also included in the park.

d) Capacities The Groundwater Division is actually responsible for 400 individual hydrogeological surveys for dry villages and towns; 40.000 sq. kms. of hydrogeological investigation and mapping on 1/100,000 scale, and resistivity sounding at 400-600 points, yearly.

In addition, the Division averages a total drilling depth of 82,000 m. annually which consists of 40,000 m. of groundwater exploratory wells, 20,000 m. of drinking water wells, 12,000 m. of foundation and 10,000 m. of drainage test holes. Thus, 180-200 test wells and 20-250 drinking water wells are drilled every year. In subsequent

years, an increase in the equipment park and personnel efficiency will naturally result in an increase in the number of wells that can be drilled and thus will enable DSİ to perform its legal duties, at much higher rates than it is possible actually.

D - ACTIVITIES OF THE DIRECTORATE GENERAL OF STATE HYDRAULIC WORKS IN GROUNDWATER PROSPECTING

a) Investigations

(i) Investigations in drainage areas and large plains : An area amounting to 62,925 sq.Kms.has been surveyed and mapped on a 1/100,000 scale map, prior to 1956. Another area amounting to 204,000 sq.Kms.has been surveyed and mapped between 1956 and 1961,bringing the total to an actual 266,926 sq.Kms.in 134 different drainage areas and large plains.

An additional 48,617 sq.Kms.of hydrogeological prospection and mapping in 19 drainage areas and large plains is scheduled for the fiscal year 1962.

(ii) Investigations for supplying drinking-water : The number of individual hydrogeological investigations made to date for supplying drinking water to dry villages, towns and cities is as follows :

120 before 1956, 1,154 between 1956 and 1962

For the fiscal year 1962 investigations for supplying drinking water to 400 military garrisons are scheduled.

(iii) Geophysical Investigations An area amounting to 3,333 sq. in four different plains has been surveyed between 1956 and 1960, by award of contract. An additional area amounting to 2, 150 sq. Kms.was surveyed by force-account in 1961. A total area of 8,800 sq.Kms.in 5 plains is scheduled for the year 1962.

b) Well Drilling

(i) Exploratory Drilling : III Exploratory wells in seven different drainage areas and large plains have been drilled prior to 1950, and 828 in 63 different plains during the period 1956-1961. The total depth of exploratory wells drilled to date amounts to 179,412 m.

Furthermore, according to the 1962 programme, 205 exploratory wells with an approximate total depth of 40,000 m. are to be drilled this year.

(ii) Well Drilling for Supplying Drinking-Water : 83 drinking-water wells for villages,towns and military garrisons were drilled during the period 1952-1956,and 618 during the period 1956-1961.

225 more drinking-water wells will be drilled in 1962.

Drinking-water wells are equipped with centrifugal,deep well or manual pumps, depending on well characteristics and demand. Meanwhile, progress is being made towards using wind energy to produce groundwater for drinking and irrigation purposes.

(iii) Drilling Work for Foundation and Drainage Investigation : 16,144 m. of foundation investigation test holes were drilled during the period 1957-1961.According to the programme,17,430 more m. of test holes are to be drilled this year.

16,979 m. of drainage investigation test-holes are drilled to date, of which 870 m. were completed by award of contract and 16,109 m. by force-account,during the period 1956-1961.

According to the programme for 1962, 8,900 m. test holes are to be drilled this year.

c) Training and Publication Activities :

(i) Technical Personal Training : Technical personnal training was first started at the Institute of Hydrogeology founded by UNESCO as an annex to the Technical University of Istanbul. Young engineers, geologists and geophysicists were offered theoretical training in groundwater for two 3-months semestres in the class and practical training for one 3-month semester in the field.

In addition to these, AID, UNESCO and other foreign technical Aid Fellowships were awarded during the period 1956-1961 to 14 technical personnel for training in the U.S.A. and France, in groundwater prospection and well drilling.

Furthermore, for the purpose of training technical personnel within the Division, miscellaneous training courses and seminars are conducted every year during the winter season.

(ii) Field Personnel Training : Winter courses are conducted every year for training drillers, and aids, foremen and labour engaged in groundwater activities in the field, where they are taught and shown the latest techniques of the profession.

For the first time this year 2 courses were conducted in DSİ regions for training groundwater foremen and pump crews.

(iii) Publications : Due consideration is given to the publication of technical literature in training all kinds of personnel. Miscellaneous technical brochures and instructions are issued and technical articles written in foreign languages are translated into Turkish.In addition, a groundwater bulletin is being published since the beginning of the year 1962.

E - METHODS USED BY THE DIRECTORATE GENERAL OF STATE HYDRAULIC WORKS

a) Groundwater Prospecting in Drainage Areas and Large Plains : Groundwater prospecting in drainage areas and large plains is performed with the purpose of (1) determining the depth, the thickness, the boundaries, the yield and the water quality of the aquifers existing areas agricultural irrigation and development are possible; and (2) investigating the possibility of resorting to them as reliable sources of irrigation water supply or for other uses.

Upon completion of such surveys, a preliminary planning report is prepared,and after published,is put at the disposal of all concerned with groundwater irrigation operations in these areas.

The following procedure is adopted during groundwater prospecting in drainage areas and large plains already scheduled among the activities of the groundwater Division of DSİ from the beginning until such time as a preliminary groundwater planning report is prepared for every area in question.

(i) Hydrogeological Investigations : Hydrogeological surveys constitute the first step in the groundwater investigations made by DSİ in a drainage area or a large plain.

The same documents that are made use of in the surveys for domestic water supply purposes discussed in Part I, are mainly also made use of in these surveys. In addition to these documents, surface water preliminary reports, flow records,soil classification maps, irrigation dosigns,etc.,are also made use of.Unfortunately,such documents are not yet available for every area to be surveyed.

Generally,1/100,000 scale maps are used during surveys and all data are recorded on these maps.Recently,hydrogeological surveys are being run in some important areas,where 1/25,000 scale maps are used.Aerial photographing being too recent a development,no application of it to groundwater surveys is made yet.

During hydrogeological field surveys,the geology, the tectonic structure,the lithology of the basin,the groundwater replenishment and storage areas within the same basin,are investigated and results are recorded on 1/100,000 scale maps.

Every spring,well,stream and stagnant body of water is studied individually; its location is marked on the map and its characteristics are recorded on separate forms.Necessary measurements are made in water quality is determined by field analysis;moreover,water samples are taken for laboratory analysis.

Existing geological maps are controlled and revised in the field,geological cross-sections are drawn and lithologic characteristics are determined and recorded on the maps.

Probable groundwater replenishment,flow and storage areas and water-bearing formations exiwting in the basin,are determined.

All inhabited areas within the plain are studied individually,and data are recorded in appropriate forms.Probable groundwater basins are located and sugges-

tions are made about the location, type and depth of exploratory wells to be drilled, and whether or not drilling must be continued to bed-rock, for the purpose of exploring the subsurface geologic structure, and to determine the qualitative characteristics of aquifers existing in the basin.

All operations discussed above and the results obtained are put together in a hydrogeological investigation report as outlined below :

Hydrogeological Investigation Report : -Summary and results -Introduction

Previous Investigations: -Geography -General -Topography -Hydrography -Climatology -Plant Cover -Agriculture and live stock -Industrial Development -Settlement and Distribution of Population.

Hydrology : Streams -Stagnant waters -Springs -Hot water springs and mineral waters -Wells -Shallow Wells -Deep Wells -Present Uses

Geology : General -Stratigraphy -Tectonic structure -Economic Geology -Paleogeography

Hydrogeology : Relation between lithology and groundwater -Relation between tectonic structure and groundwater -Infiltration and recharge areas -Groundwater replenishment and movement -Groundwater losses -Groundwater storage- Groundwater level Fluctuations -Groundwater chemistry -Possibilities for groundwater use

Conclusions and suggestions - Documents - Appendix : Hydrographic maps - Hydrogeological maps -Geological cross sections and diagrams -Local geological cross sections -Water analysis tables and diagrams -Statistical tables -Well logging -Soil classification maps

(ii) Geophysical Investigations : In areas where hydrogeological surveys have been completed and where certain geological problems still remain unsolved, suitable geophysical methods and applied prior to and simultaneous with, or upon completion of exploration drilling, with an attempt to find solutions to each problem respectively, These surveys are run essentially for the purpose of investigating and obtaining valuable information about the existence of faults, the thickness of the alluvial deposits and other water-bearing formations, the depth at which aquifers are located, and in some cases, to determine the location of the impervious strata.

The Groundwater Division of DSI owns 3 Wittera Resistivity and I SIE 24 Canal Seismic-refraction apparatus, Of these, 3 Resistivity apparatus are in operation; the Seismic-refraction apparatus will be put into operation sometime during 1963.

Resistivity surveys are generally run according to a rectangular system and in certain cases, over individual points of cross-sections. Wenner and Lee methods are used in the field in taking resistivity measurements. In the meantime, potential drop ratio and fault investigation methods are also applied, depending on the type and nature of the problems encountered.

During the seismic surveys to be started this year, either one of the seismic-refraction methods will be used according to necessity.

The Department also owns and operates 4 station-wagon mounted electrical well-logging apparatus, Two of these are single-point type and the remaining two are of the 16" and 64" Single-Point and gamma-ray recorder type.

These apparatus are used in logging exploration and drinking water wells drilled by DSI. The logs are used in the determination of samples, in locating the aquifers and in casing the wells.

(iii) Exploratory Well Drilling : Upon completion of hydrogeological, and in certain cases of geophysical investigations, exploratory well drilling is performed according to the suggestions made in the survey reports, for the purpose of determining the subsurface geology of the plains, the depth and the thickness of the water-bearing formations, the quantity and the quality of the water and the hydraulic characteristics of the aquifers The survey reports belonging to areas scheduled for exploratory drilling are examined by a joint committee of experts and the

authors themselves, discussed, and finally, written instructions are prepared for the location and depth of wells to be drilled and the kind of tests to be performed on the site. Copies of these written instructions are mailed to the interested Regional Directorates of DSİ. and the drill-camps attached to them. Drilling is performed by the drill-camps by force-account and using DSİ rigs and equipment, according to these instructions under the close technical supervision of the Groundwater Division of DSİ, and the author of the survey report, the latter at the same time acting as responsible geologist on the site, when practically possible.

Exploratory well drilling is generally performed using 1500 capacity rotary drill rigs, and weather permitting, in three shifts during a full 24 hr. day. Under certain conditions percussion rigs are also used.

Generally the diameter at the start varies between 12" and 15" and it is reduced according to necessity as drilling progresses. The hole depth varies from 200-300 m., depending on local geological structure, depth to water table and depth at which the bedrock lies. Samples from the cuttings are taken every meter or at every change of formation, and at even the slightest indication of water. Core samples are also taken from certain horizons when necessary.

The basic principle adopted in exploratory drilling is to perform separate pump tests for every aquifer, and determine its characteristics entirely independently from the others. For this purpose, after performing qualitative and quantitative tests for the first aquifer encountered in a well, the aquifer is completely shut off by grouting, casing or by any other suitable method, depending on the existing geologic and drilling conditions, and drilling is resumed, following which same operations are repeated in the same manner for every subsequent aquifer. In certain other areas, a seperate well is drilled for every aquifer and necessary tests are run entirely independently from each other.

Exploratory wells are located according to a rectangular system, and thus a network of transversal and longitudinal cross-sections of the area can be worked out. Generally in plains where exploration work is carried on, there exists no well one can refer to for enlightening data concerning local subsurface conditions; all one must depend upon is the information offered in the hydrogeological survey report. For this reason, pilot holes are drilled prior to exploratory wells, at locations where surface structure of the plain and the groundwater possibilities can be figured out best. Usually, whether exploratory drilling should proceed or be completely abandoned, depends on the results obtained from pilot wells.

In alluvium, in neogene and other sedimentary formations, exploratory drilling is performed with rotary rigs with mud circulation, whereas, in cracked and fissured calcareous formations, where often mud circulation losses occur, compressed air is used instead. In certain areas where drilling must penetrate hard rocks, such as basalts and andesites, down the hole hammer is used.

Temporary or permanent shutting off of an aquifer, when necessary, is done by grouting, cement jetting or by casing.

All phases of drilling operations, whether exploratory or other, are recorded on regular forms and diagrams and are saved for later use.

(iv) Laboratory Work : Water samples taken from wells, springs, foundations, etc., during prospection surveys are immediately tested in the field for hardness, alkalinity, Cl and PH by colorimetric methods, using the Palo kit, and for electrical conductivity using the conductivity meter, LBR. The salt content is then calculated from which Sodium Potassium and Sulphate contents are computed. The point in making these tests is (1) to obtain quick first-hand information about the quality of water, and (2) to cut down the number of samples to be taken. Any aquifer yielding water of unsuitable quality is shut off on the spot. Thus only one representative sample of 1 lt. is taken from each group of suitable sources where field tests have shown a

similarity in the quality of water yielded, and shipped to the Main Lab. For a complete chemical analysis.

Water samples are tested in the main Lab.For PH,EC, Na, K, Ca, Mg, Co_3, Cl, So_4, No_2, NH_3 and organic matter contents and % Na, SAR (Sodium Absorbtion Ratio), RSC (Residual Sodium Carbonate) values and the class of water for irrigation purposes are reported.

When results of analysis of water samples taken from prospective sources of drinking water supply show any signs of nitrates and ammonia existing in the water, additional samples are taken in sterilized containers for further bacteriological analysis. But, the only official agency in the country where bacteriological tests can be performed is the Central Health Conservation Institute in Ankara. Usually, considerable time elapses between the time the sample is taken and the time it reaches the Institute for analysis. It is therefore at present impossible to obtain true representative samples at the Laboratory in time for bacteriological analysis. The solution to this problem is of course (1) to establish in every region adequate laboratories that can perform bacteriological analysis to give dependable results within a reasonably short time, before the sample deteriorates, and (2) until such to make use of portable analytical kits, like the millipore, which will serve the immediate purpose temporarily.

Macroscopic and microscopic tests of soil samples taken from wells are performed in the Paleogeological Laboratory of DSİ. Thanks to the results of these tests the stratigraphy, the probable thicknesses and the water bearing properties of the formations penetrated are determined.

(v) Groundwater Level Observations : Out of approximately 940 exploratory wells drilled until the close of the year 1961, in 70 different drainage areas and plains, 678 are being used as regular observation wells, to determine monthly and seasonal groundwater level and artesian head fluctuation and the effect of pumpage,climate and other factors on the water table.

In deciding on the location and the number of observation wells in every plain or drainage area, care is taken to choose the ones that will best represent the level fluctuation of the part of the area in which they are located. Monthly observations are made in each of the wells and the results are recorded on separate forms. Observations are conducted by Regional Directorates of DSI.,and records are taken by technicians trained for and assigned to this job. These records are evaluated and field for reference after ther are plotted on a separate graph for each individual well.

Generally, tapes or electric sounders (m.scope)are used in taking water level readings.Artesian heads measured by pressure gauges or manometers. Actually no automatic recorders are being used.

Besides water level observations in wells as described above,surface streams, lakes and reservoirs are also regularly gauged by the Planning and Programming Division of DSİ.These records are referred to in the parts titled "Groundwater Investigations".

(vi) Preparation of Planning Reports : A groundwater planning report is prepared following completion of exploratory drilling in an area, and in the light of the hydrogeological and geophysical surveys and the results obtained from drilling, also of any documents available belonging to previous work of the same nature.

A groundwater planning report consists of the following parts :

(i) - Purpose,Summary and Suggestions : In this part a summary of the report is given where the purpose of the report, the conclusions reached, and suggestions in connection with the use of groundwater are clearly indicated.

(ii) - General Information : In this part, information about the general geography, topography, climatology, soil structure and characteristics, plant cover, agriculture and live-stock farming, population and settlement conditions,commercial

and industrial development are presented. Also, all documents relating to the above-mentioned items are fully discussed.

(iii) - Geology : In this part, all geological work done in the area to date is discussed. Using these and the results obtained from exploratory drilling, paleography and lithologic characteristics of the area are indicated in as much detail as possible. In relation with these, maps, profiles and diagrams are prepared and interpreted. The logs of wells falling within the plane of cross-sections of areas where exploratory drilling has been completed, are made use of in correlating such wells.

(iv) - Hydrology : In this part, detailed information is given about streams, lakes, reservoirs, springs, shallow and deep wells, galleries, and the results of groundwater level fluctuation observations. All these and their characteristics are marked on hydrogeological maps.

Results of stream flow and water table level measurements taken in the area are discussed. These are checked against climatological records, and the effect of climatological factors on the stream flow and water table fluctuation is studied. The result of this work is presented in the form of graphs and diagrams, and are commented on before closing up. In areas where frequent flow measurements are taken, infiltration is determined with the aid of observation records.

(v) - Hydrogeology : In this part are discussed, and valuable information given about, groundwater-bearing characteristics of different geological formations, the relation between the tectonic structure and lithologic nature of the formations and groundwater, the location, the depth and extent, the hydraulic and chemical characteristics of the aquifer, the groundwater replenishment and storage areas, and the standing of existing exploratory wells.

Areas are located where groundwater is suitable both in quantity and quality, for use for a variety of purposes. The safe total yield of the area, the radii of influence, the depth, the yield, and other characteristics of prospective wells are determined.

In determining the safe yield, the following methods are used :

1 - Evaluation of pump test results according to Darey's Law.: By evaluation pump test results, permeability, transmissibility and storage factors are determined for every aquifer, from which the radii of influence of wells to be drilled in the area, the safe yield from each well, and resulting drawdowns at the end of definite time periods, are derived. Generally Theis and Jacob methods are used in the evaluation of test results.

This procedure is only recently applied in the Division, therefore it is needless to say that in earlier surveys no such use has been made.

2 - Estimating percolation by way of hydrological inventory in the area.

This method has been used in preparing earlier preliminary groundwater planning reports. For comparison purposes, use is made of this method also in estimating percolation.

In such work, evaluations are madeby the use of Thornewaite method, parting from climatologic factors like precipitation, temperature and sunning.

3 - Where sufficient stream flow observation records are available, total percolation is estimated from the influent water, and from precipitation. In these estimates approximate infiltration rates are taken from different formations. Meanwhile, attempt is made towards obtaining results by deducting water loss through evapo-transpiration from the total annual influent water.

4 - Also for the purpose of comparison, and basing on the crop patterns, type of soil, and depth of tool zone in the area, and using infiltration rate graphs of similar areas prepared after tests run in miscelaneous countries, infiltration is estimated for a number of areas and plains in this country.

Due to the lack of long groundwater level observation records in this country, computation of safe yields could not be made from water table fluctuations.

(vi) - Geochemistry : In this part are given, the discussion and evaluation of test results of water samples taken separately from streams, springs and every aquifer in the wells.

Depending on the result of evaluation, the relation between the lithologic characteristics of the formation and the quality of water, also the influence of different formations on the quality of water, are discussed, In connection with these, semi-logarithmic, triangular and riverside diagrams are also prepared.

Results of analysis are plotted on triangular and semi-logarithmic diagrams. By examining these diagrams it can readily be determined which formations are responsible for the change in the anions, cations and salt contents.

Electrical conductivity, chlorine, sulphate, and Ca-Mg values for springs flowing out from the same aquifer or the same formation, are marked on the maps. Furthermore, such waters are classified according to their suitability for irrigation. Results are marked on maps and riverside diagrams, meanwhile, the effect of quality of groundwater on casings and screens in connection with and corrosion, is also studied and the results noted.

(vii) - Economic Evaluation : In this part, possibilities of irrigation from groundwater are discussed from the point of view of economy. The cost per cu.m. of water, or the total cost of operation per hectar of irrigated land,are analysed for both flowing well and pump irrigation. The increase in returns per hectar with respect to the kind of crop irrigated is calculated. By comparing costs and increases in the returns the return-to-cost ratio is computed and noted in the report.

(viii) - Documents :

The following documents are attached to the report : - 1. Topographical map- 2. Geological map -3. Geological cross sections and correlations -4. Hydrological map - 5. Static level map - 6. Specific capacity map - 7. Impervious strate contour map - 8. Soil classification map - 9. EC, SO_4, and CL contour maps - 10. Logatithmic, triangular and riverside diagrams of water analysis - 11. Statistical tables, well-logs,water analysis reports, etc.

b) Groundwater Prospecting for Supplying Drinking Water : All prospection for and construction of water supply facilities for villages and towns under 3,000 population and military garrisons come under DSI's jurisdiction according to Laws Nos.7478 and 178 already in force. Drinking water supply possibilities for such communities areinvestigated according to a definite programme, communities where surface water supplies are available and construction is economical,drinking water demands are met through such sources. Where groundwater proves to be economical or the only source of supply available, a hydrogeological investigation precedes any other action. The results of such investigations are examined jointly by the Groundwater and the Drinking Water Divisions of DSI, and discussed and a decision is taken on either surface or groundwater sources to be considered in the project, depending on whichever source is most economical and convenient to be developed. Upon such decision, and on the event of groundwater development, drilling instructions are prepared similar to those for exploratory drilling, and wells are constructed by the drill-camps,accordingly,again under the close technical supervision of the Groundwater Division.

Both rotary and percussion type drill rigs are employed in drinking water drilling. Depending on local conditions, mud circulation, compressed air or down the hole hammer methods are used in drilling with rotary rigs.

The principle in drinking water is to drill wells at such depths as it is necessary, to provide water of adequate quantity and quality to meet the local demand. For this reason, every aquifer penetrated is tested in succession, any aquifer showing any indication of salt content or contamination, is shut off completely, and drilling is resumet and continued until adequate quantities of good water is available, at which time drilling is discontinued. On account of these accepted principles, the depth of a drinking water well seldom exceeds 100 m.

For pump setting reasons, producing wells are cased with 8" pipes down to 40 m., and rarely, to 60-80 m.To prevent surface contamination, well-heads are cased for a depth of 5-10 m.,with larger diameter guide pipes,and grouted. Such wells are equipped with suitable pumps, storage and distribution facilities are constructed and the whole system is put to public use.

(i) Auxiliary Documentation

Maps : 1/800,000 and 1/100,000 scale geological and topographical maps of

Turkey are prepared bu MTA, also 1/25,000 and 1/100,000 scale topographic maps prepared by General Directorate of Mapping,are madeuse of during individual hydrogeological investigations.

Meteorological Records : Meteorological bulletins covering 20-30 years or longer periods,regional precipitation,temperature,humidity,and wind records for the whole of Turkey,also evaporation records for some regions, are available.

Statistical Records : Miscellaneous reports on previous geological,hydrogeological and geophysical surveys&records on oil exploration surveys and drilling,or any other document on drinking water or other surveys run by DSİ.,in the vicinity of the village or town,are also made use of during investigations whenever available.

(ii) Field Operations

Field operations for drinking water prospections are briefly outlined as follows : Every well, spring, storage facility and fountain in the vicinity of the village or town in question,is individually investigated, its yield is either taken from records when available, or measured and estimated on the spot when possible.Water samples are taken and subjected to field analysis also.

In addition to estimating actual and future water demands of villages and towns, also what part of the demands are already met by existing sources,and e possibility of supplying the balance from other sources,is also investigated.

The geology,the tectonic structure and the lithology of the surrounding is surveyed,as the result of this,existing water bearing formations, and the characteristics and the possibility of re-charge are determined.

All this work is traced on 1/100,000 and 1/25,000 scale maps and forms, and where convenient,drinking water wells are located and approximate locations are shown on the maps.

(iii) Preparation of Investigation Reports: Following completion of all work described above,a hydrogeological Investigation Report is prepared according to the following outline: -

- SUMMARY : A brief account of the performance and the conclusion reached is given together with the suggestions made in the report.
- PURPOSE : Following are clearly cited : -The purpose of the investigation, -The name and the qualifications of the surveyor, - The methods used and the time spent
- GENERAL GEOGRAPHY : -Location of the area, its magnitude, etc., -Topography,type of land, -Population, settlement and road conditions, -Economic and industrial developments.
- HYDROLOGY : -Surface waters, -Springs, -Ordinary wells, -Climate.
- EXISTING WATER SUPPLY CONDITIONS AND FUTURE WATER DEMAND : Present water demand, -Future water demand, -Existing water supply.

Location and yield of every spring, fountain, well and storage, together with the quality of water and other characteristics. The total demand and what part of it is already supplied.

Supply possibilities : These sources which should be resortedto, to meet the demands, are pointed out. A detailed discussion of either surface or groundwater supply is presented,whichever is more promising.

- HYDROGEOLOGY : -General geology, -Stratigraphy, -Tectonic, -lithologic and water-bearing characteristics of the formation, -Groundwater re-charge and movement, -Water-bearing formations.
- DRILLING SITES : - Definition of locations, -Suggestions concerning depth, size, etc., of wells to be drilled Results and suggestions.

Results and suggestions about to be taken towards meeting water demands are given in the order of importance.

c) Methods of Drilling in Foundation and Drainage Investigations

(i) Foundation Investigations : All foundation investigation drilling in connection with planning and investigation activities of the Planning and Programing, and Design and Construction Divisions of DSİ, is performed by the Groundwater Division,upon the former Divisions request.

In foundation investigation of sites for dams,reservoirs,bridge piers,pumping structures, etc.,core (diamond) drilling,pressure tests and undisturbed sampling are performed.

The specific application of core drilling by DSİ, in foundation investigations, comprises the study of the geological structure of the site for the purpose of finding out the zones of faulting and brecciation, if any. To do this,continuous core drilling is performed and several pressure tests are run.

In some sites the depth to bedrock is investigated. In others, data is collected-especially in sedimentary rocks-for weak, permeable and swelling zones, at even greater depths.

Water transmitting capacity of the rock is also investigated due to its importance since it controls the extent of leakage from dams and reservoirs.

Core drilling is performed by skid-mounted rotary core drills.The hole depth seldom exceeds 80 meters, the hole diameter varying between NX and HX sizes.

Single or double tube core barrels are used in coring. Undisturbed sampling is also carried on through the overburden.

Pressure tests are run in core drilled holes to find out the permeability of the underlying rock and the character of the fractures,seams, joints and cavities. Single or double packer type permeability testers are used in pressure tests which are performed in conformity with USBR GR97, designation "B" test.

Gravity type permeability tests are also run in the overburden.Using the same procedure described in USBR GR97,designation "E" test.

(ii) Drainage Investigations : In plains where (irrigation is practiced or will be eventually) prospection surveys and planning work has been either started or completed by the Planning and Programming Division of DSİ, drainage investigation drilling is performed by the Goundwater Division at locations where water table creates a problem.

Generally, drainage investigations are carried out to determine :

1 - The depth of the barrier strata
2 - The stratification of the underlying formation within 20 meters of the surface
3 - The existence of water-bearing formations
4 - The possibility of water-bearing formations being interconnected by hydraulic means.
5 - How much the water table can be lowered by pumping from wells.
6 - The spacing and the type of wells to be drilled,if the water table can be lowered.
7 - The suitability of the water pumped from wells for irrigation.
8 - Whether high water table is caused by seepage from underlying artesian aquifer into the overlying water table zone.

To collect the above data and to find an answer to the problem in drainage investigation drilling, continuous drive sampling is performed. The samples thus collected are packed in special cylindrical galvanized metal tubes and are shipped to the Main Laboratory for mechanical and chemical examination. In wells where water bearing formations are penetrated, pump tests are run and water samples are collected for chemical examination.

From pump test data, values for coefficient of transmissibility and storage capacity are calculated. Drilling operations are generally carried out with percussion rigs. Well depths seldom exceed 20 m. the hole diameter varying between 6" and 8". Generally two observation wells are drilled before test pumping for measuring the drawdown around the pumped well, against time. Later, one of the wells is saved for use as a permanent observation well for data on groundwater level fluctuations all year round.

The whole procedure is recorded in detail on special forms and diagrams.

The result of the field and laboratory work are evaluated and correlated to take necessary decisions towards solving the problems confronted with.

F - ANNEXES :

(b) GROUNDWATER PROSPECTING ACTIVITIES IN TURKEY

I - Hydrogeological Basin Studies

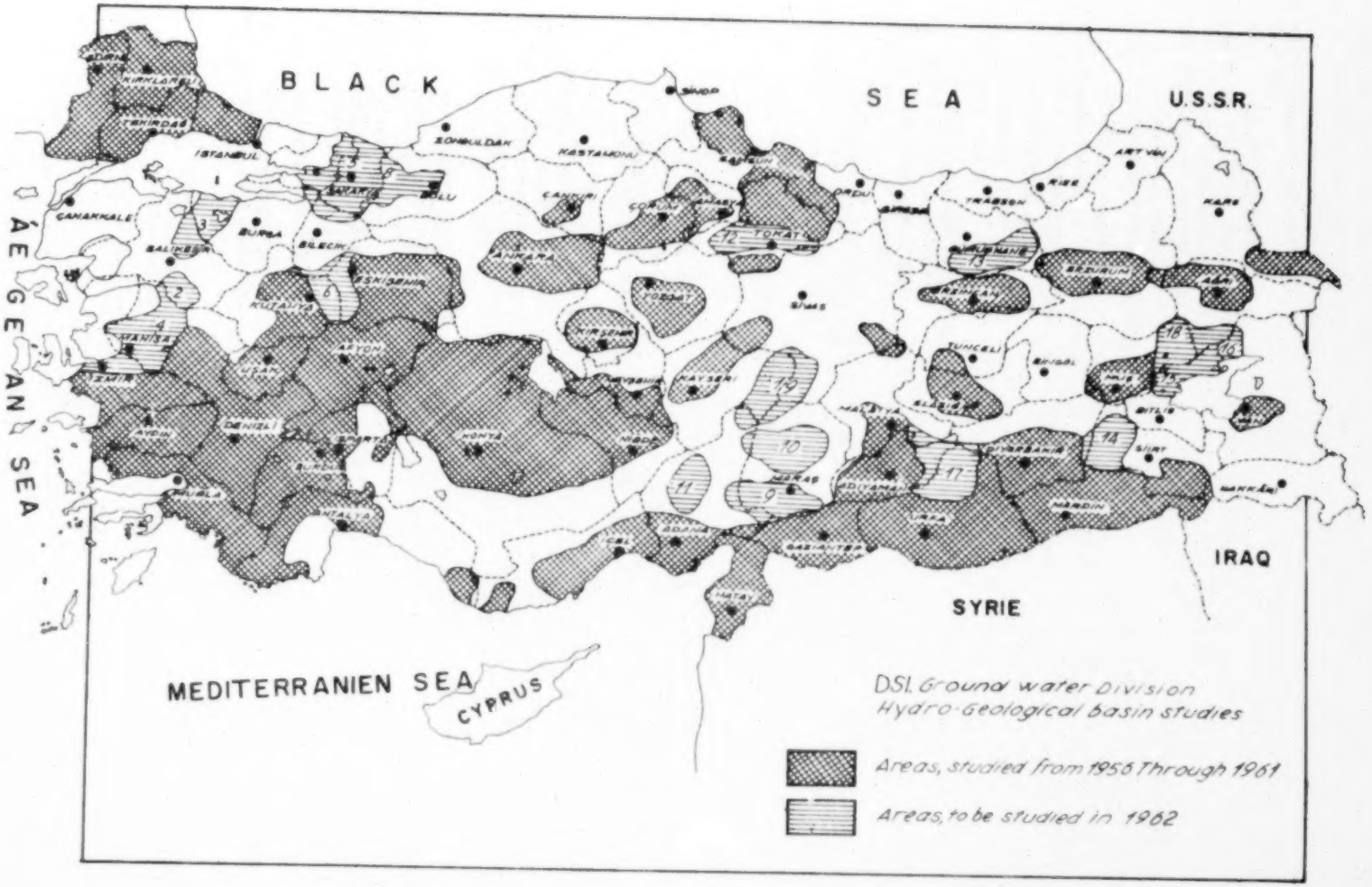
Years	N. Of plains studied	Area in sq. km.
To end of 1956	19	62.925
in 1957	21	25.917
" 1958	22	31.984
" 1959	12	44.101
" 1960	27	59.310
" 1961	33	42.689
" 1962	19	48.617
Total	153	315.543

II - Exploratory Wells

Years	N. of Wells Drilled				Total Depth Drilled m.	Total Discharge L/Sec.
	Flowing	Non Flow	Dry	Total		
To end of 1956	4	67	40	111	22.305	1.397
in 1957	20	102	49	171	32.525	2.020
" 1958	14	119	35	168	30.770	1.684
" 1959	38	111	46	195	42.146	1.913
" 1960	21	84	12	117	25.467	1.076
" 1961	50	88	39	177	66.043	1.691
" 1962	38	115	21	174	24.706	1.230
Total	185	686	242	1113	243.962	11.011

III - Drinking water wells

Years	N. of Wells Drilled				Total Depth Drilled m.	Total Discharge L/Sec.
	Flowing	Non Flow	Dry	Total		
To end of 1956	7	43	33	83	8.526	273
" 1957	2	16	8	26	1.994	107
" 1958	5	55	15	75	6.715	448
" 1959	6	94	24	124	14.433	833
" 1960	24	182	38	244	26.934	1.805
" 1961	11	105	44	160	4.250	967
" 1962	8	60	15	83	7.226	3.375
Total	63	555	177	795	70.078	7.808



GROUNDWATER PROSPECTION MAP OF TURKEY

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